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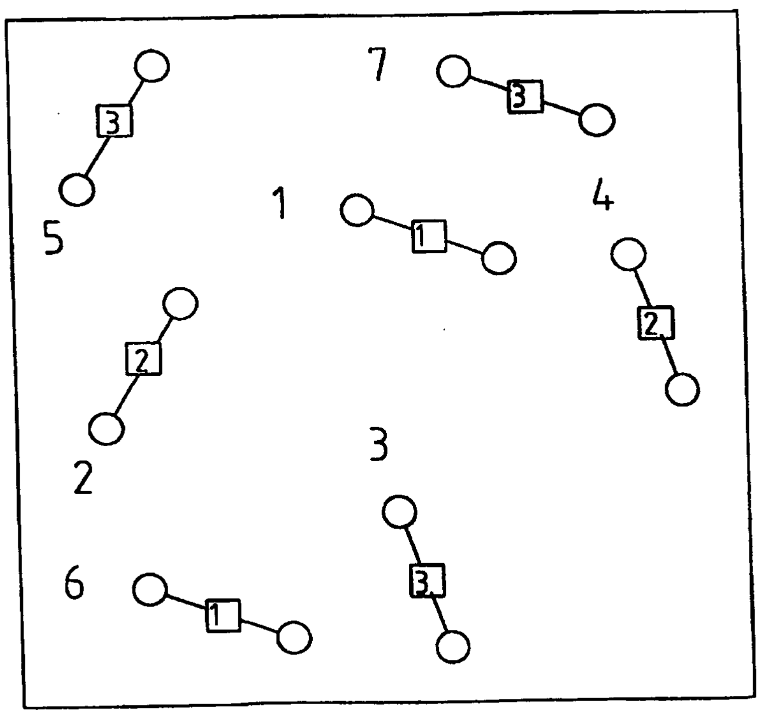
(54) Title: A METHOD TO ALLOCATE CHANNELS FOR A FIXED RADIO LINK OPERATING IN AN NON-COORDINATED FREQUENCY BAND

(57) Abstract

The present invention provides a method for allocating channels for a fixed radio link operating in an non-coordinated frequency band, wherein a predetermined and fixed number of channels are assigned to a plurality of radio links operating within a predetermined radio environment area, which method comprises the steps of allocating a respective distinct one or several of said predetermined number of channels to the corresponding number of radio links which are commissioned first, and for each additional radio link to be commissioned in excess of the number of predetermined channels, measuring the interference of each available channel allocated to the already commissioned radio links, and/or measuring the distance from each of the already commissioned radio links having an available channel allocated thereto, and choosing the channel to be allocated to the respective additional radio link to be commissioned based on the interference and/or distance measurement.



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A method to allocate channels for a fixed radio link operating in an non-coordinated frequency band

FIELD OF THE INVENTION

The present invention relates to a method for allocating channels for a fixed radio link operating in an non-coordinated frequency band.

BACKGROUND OF THE INVENTION

Radio links have traditionally been operating in regulated radio environments or regulated bands (frequency bands), respectively. That is, in a given radio environment or a predetermined local area in which radio links are to be established and/or maintained, only a predetermined overall bandwidth is available for such radio links.

Therefore, the overall available bandwidth had to be divided into a plurality of channels of a respective smaller bandwidth than the overall available bandwidth, with each channel being associated to a specific frequency within the available frequency range.

Then, a radio link was established for such a specific channel or frequency, respectively.

For this case, when a plurality of radio links or so-called hops are (or may be) present within a given area, in the regulated radio environment, the channel choice is based on coordinated frequency planning.

That is, the respective channel to be used for a specific radio link at a time is predetermined. Nevertheless, in such a regulated radio environment, the channel to be used for a link may be changed in the course of the regulation, i.e. control, of the radio environment. Stated in other

words, a respective channel allocation for a radio link may be periodically updated and changed.

Recent developments in telecommunications have, however, lead to changes with regard to frequency allocations and have thus created possibilities to operate radio links and/or hops in non-coordinated frequency bands.

As an example European Telecommunication Standard ETS 300408 specifies the minimum performance parameters for radio equipment operating at frequencies around 58 GHz and not requiring coordinated frequency planning.

However, this means that unlike the further above described traditional radio links within a regulated (or coordinated) radio environment, those systems operating in an non-coordinated band will operate in interference limited environment. That is, the signal quality of received signals may be deteriorated due to interference phenomena caused by neighboring radio links.

Therefore, it is of increasing interest to consider how to share available bandwidth among various systems in an efficient way.

One previously proposed approach for such present day radio links operating in an non-coordinated band resides in assigning a fixed channel to each radio link or hop, respectively, already at the stage of production of the respective devices at the factory.

This is, for example, the approach adopted by the company "*Microwave Modules Ltd.*", which produces radio links for the non-coordinated 58 GHz band.

These devices which are used to establish point-to-point local networks are using fixed channel allocation principle. Various problems as explained below may arise during operation of the system.

Fig. 1 of the accompanying drawings illustrates an example for a prior art non-coordinated radio environment and the problems associated therewith.

As shown in Fig. 1, the area of the radio environment is indicated by the rectangular shaped box. Within this area, according to the shown example, only three channels (channel numbers 1, 2, 3) for radio links (hops) are available. A respective one of the hops is represented by a line connecting two small circles, the radio link being denoted with a corresponding number at one of the two circles. The channel number fixedly assigned to each of these hops is denoted by the figure in a square-shaped box inserted into the line connecting respective two circles.

Now, with regard to the situation depicted in Fig. 1, hops number one to three were configured at the factory side to transmit on channels 1, 2, and 3, respectively. A fourth hop to be additionally established within the given area was also configured at the factory side to transmit on a specific channel denoted by x (x being 1, 2 or 3 in the chosen example).

Consequently, due to the arrangement or configuration of the hops and the respective fixed channels thereof, a channel collision between one of hops number 1, 2 or 3 and hop number 4 is extremely likely to occur in the depicted situation, irrespective of the channel number (channel 1, 2, or 3) hop number 4 may be configured for transmission.

The term *channel collision* in this connection means cross-talk or interference phenomena which are likely to occur between respective hops and result in a decreased transmission quality. In particular, a channel collision is defined as occurring for a radio link for which a ratio of S/I is below a given collision threshold TH_C, i.e. $S/I < TH_C$, with S representing signal power and I representing interference power from one or several other radio links within the same radio environment.

That is, with reference to the schematically depicted example of Fig. 1 there may either occur a channel collision between hop number 4 and hop number 1 in case hop 4 transmits on channel 1, or a channel collision between hop number 4 and hop number 2 in case hop 4 transmits on channel 2, or a channel collision between hop number 4 and hop number 3 in case hop 4 transmits on channel 3.

To be precise, for a given number of randomly placed hops within a radio environment of a well defined area, channel collisions between respective hops are very likely to occur.

This, in turn, severely limits the number of radio links (hops) per area (km^2) of the radio environment to a value much lower than a value which should desirably be achieved.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide a method for allocating channels for a fixed radio link operating in an non-coordinated frequency band, which method allows the number of links that can be commissioned in a given area to be increased by a large factor while

simultaneously lowering the above described risks of the non-coordinated frequency band.

This object is achieved by a method for allocating channels for a fixed radio link operating in an non-coordinated frequency band, wherein a predetermined and fixed number of channels are assigned to a plurality of radio links operating within a predetermined radio environment area, comprising the steps of allocating a respective distinct one or several of said predetermined number of channels to the corresponding number of radio links which are commissioned first, and for each additional radio link to be commissioned in excess of the number of predetermined channels, measuring the interference of each available channel allocated to the already commissioned radio links, and choosing the channel to be allocated to the respective additional radio link to be commissioned based on the interference measurement.

Furthermore, this object is achieved by a method for allocating channels for a fixed radio link operating in an non-coordinated frequency band, wherein a predetermined and fixed number of channels are assigned to a plurality of radio links operating within a predetermined radio environment area, comprising the steps of allocating a respective distinct one or several of said predetermined number of channels to the corresponding number of radio links which are commissioned first, and for each additional radio link to be commissioned in excess of the number of predetermined channels, measuring the distance from each of the already commissioned radio links having an available channel allocated thereto, and choosing the channel or channels to be allocated to the respective additional radio link to be commissioned based on the distance measurement.

Stated in other words, according to the present invention, instead of using a fixed and pre-set channel for the fixed radio link, a channel is assigned when commissioning the link, depending on interference measurement results and/or distance measurement results.

Accordingly, due to the above described methods for allocating channels for a fixed radio link operating in a non-coordinated frequency band, the present invention provides the advantage that the number of links (hops) that can be commissioned in a given radio environment area can be increased by a large factor. At the same time, the method according to the present invention effectively allows the risks of the non-coordinated frequency band to be significantly lowered.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following, the present invention will be described in greater detail with reference to the accompanying drawings, in which:

Fig. 1 is an example of a configuration of hops in a radio environment area operated in an non-coordinated frequency band according to the previously known approach;

Fig. 2 is an example of a random configuration of hops in a radio environment area operated in an non-coordinated frequency band according to the method of the present invention; and

Fig. 3 is a diagram showing the effects on the number of hops per area as a function of signal interference ratio (SIR) requirements for a given value of collision

probability P, obtained by the method according to the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

According to the present invention, instead of using a fixed pre-set channel for the fixed radio link like in the prior art, a channel (or even more than one channels) is (are) assigned when commissioning the link. In particular, such channel assignment may be effected manually or automatically.

The basic methods for choosing one (or several) channel(s) are as follows.

Firstly, the interference of each available channel is measured and based on the measurement result an appropriate channel is chosen. This may be the channel with the lowest interference power or a channel having an interference power below a given interference threshold level TH_I, which level represents an admissible interference power limit. Alternatively, any of available channels with a ratio S/I above a collision threshold level TH_C for which no channel collision occurs may be chosen.

Secondly, due to the fact that the channel interference strongly depends on the distance between radio links or hops, respectively, in some cases it may be sufficient to choose one (or several) channel(s) to be used by the fixed radio link based on the results of a distance measurement. Thus, it is conceivable to dispense with interference measurement and to perform channel allocation for respective radio links based on distance measurement results, like for example those results obtained by using GPS (Global Positioning System). That is, the choosing of a

channel or channels for the newly commissioned radio link may be effected by choosing the channel (or channels) which are used by the most distant ones of the links commissioned earlier. Alternatively, any of the channels which are used by radio links at a distance which is larger than a given distance threshold TH_D may be chosen.

Fig. 2 of the drawings shows a situation within a radio environment of specified area in which channels for a fixed radio link operating in an non-coordinated frequency band are effectively allocated according to the method of the present invention. It should be noted that for simplification of explanation, in the example of Fig. 2 it is assumed that for each hop only a single channel is provided. However, it is also possible that a hop uses more than one channel and that all channels of a respective hop, i.e. one or several channels are commissioned according to the method of the present invention.

Since the symbols used in Fig. 2 have the same meaning as those already explained in connection with Fig. 1 further above, a repeated detailed explanation thereof is omitted.

It should, however, be noted that the channel or channels on which a respective radio link (hop) transmits is not a fixed pre-set channel for the fixed radio link but the channel may be selected or assigned at the time of commission. In addition, the number at one end of the hop indicating the number of the respective hop now additionally represents the order in which the hops are commissioned.

Referring now to the example as shown in Fig. 2, under the assumption that seven hops are placed in the radio environment of fixed area and that the total number of

available channels is three, the method or algorithm according to the present invention works as follows.

For the first three hops that are commissioned, distinct channels (channels 1 to 3) are chosen. For the fourth hop, the channel that is used in the most distant of the existing links is chosen, i.e. channel number 2 in the depicted situation. Further, in the shown example, for the fifth, sixth and seventh hop subsequently assigned, then the channels number 3, 1, and 3 are assigned, respectively.

This leads to a situation in which for each new link to be established, a channel that is used far away tends to be chosen, since for such a channel the lowest interference may be expected to be measured.

Although the above description has been made with reference to distance measurement, the same algorithm applies for channel assignment based on interference (interference power) measurement. For example, in a radio environment in a mountainous / hilly area, the received interference power of a very close neighboring radio link due to mountains between the radio link to be commissioned and the neighbor hops may be less than in a plane environment. Thus, the channel assignment based on mere distance information may be inappropriate. Instead, in such a case, channel assignment can be based on the evaluation of interference measurement results as explained further above. Moreover, it is also conceivable to combine both methods and to choose a channel to be assigned based on both measurement results, i.e. to choose a channel by evaluating a combination of distance and interference measurement results.

As a random network of links is built, it automatically adjusts itself to a configuration where links which use the same frequency tend to be far away from each other.

The improvement in the capacity for a given probability of channel collision is thus substantial.

Fig. 3 of the accompanying drawings shows a diagram schematically illustrating the achievable improvement in capacity. In detail, Fig. 3 shows a plot of the number of hops (N) per area (km^2) as a function of signal interference ratio (S/I) requirements (SIR requirement) for a given value of the collision probability P (P=0.01 in the given example).

The meaning of the channel collision probability P as a used parameter in the Fig. 3 diagram is as follows. If it is known beforehand that a number of N radio links or hops are installed randomly within a given area, then the channel collision probability P is a measure of the likelihood that a new link, i.e. the (N+1:th) that is installed in a random place will not function, since, for example, the signal to interference requirement cannot be satisfied. For a large network of many non-coordinated links the channel collision probability defines the fraction of the links that will require special attention after installation. Preferably, this probability should be very small (typically a few percent at most), since otherwise it will become very difficult to build networks using non-coordinated links.

Observing or determining the channel collision probability may be done directly by collecting interference statistics from the network of links. The dynamics of the interference will be very slow since only upon installation of new links

the situation will change. The collecting of the statistics can be done either automatically or manually. The simplest manual procedure could then be based, for example, on failure reports obtained upon installation of the links.

Now, referring back to the Fig. 3 diagram, the lower curve shows the situation for the random choice of channels, while the upper curve shows the situation when, according to the method of the present invention, for each link to be commissioned the channel with, e.g., the lowest interference level is chosen.

It can be gathered from Fig. 3 that a relatively high density of links can be installed in a given area when using the present invention, without involving an undue risk that a channel collision occurs. To be precise, let us assume in the depicted example that for signal to interference requirements a threshold of 20 dB is set and let us assume that an operator building a network using non-coordinated links is willing to accept that one out of hundred links that are installed will not work immediately, which means a collision probability of P=0.01. Those links that will not work or work only unsatisfactory must be relocated or an alternative transmission must be used. According to the prior art (lower curve in Fig. 3), only about two links per square km can be installed. However, according to the present invention (upper curve in Fig. 3), about twenty links per square km can be installed.

Apparently, according to the present invention, the number of links or hops that can be commissioned in a given area may be significantly increased (about a factor of 10 or even more). At the same time, the method according to the present invention will allow the risks of the non-coordinated use, i.e. the uncontrolled use of allocated

frequencies, to be lowered. Further, based on realistic numbers for penetration of such links, however, detailed calculations show that the collision probability is very close to zero for many years into the future when the present invention is used.

Moreover, it is to be noted that substantially the same approach could be used to choose CDMA-spreading codes adaptively. Adopting such an approach would then lead to a system which would always choose the code based on interference measurements, for example, the code with the lowest level of interference.

Furthermore, judging of interference levels as a result of monitoring the channels may not only be effected when assigning a channel to a radio link to be newly established. In this connection, it is also conceivable to continuously monitor the channels within the radio environment, i.e. the fixed area, and to jump to a new channel whenever a new better channel is available. However, in such a case, appropriate countermeasures against oscillations in the non-coordinated network or band, respectively, will have to be taken. That is, indefinite changes from channel to channel within parts of the system would have to be prevented.

It should be understood that the above description and accompanying figures are only intended to illustrate the present invention by way of example only. Thus, the method according to the invention may also be used in systems other than the described. The preferred embodiments of the method may thus vary within the scope of the attached claims.

CLAIMS

1. A method for allocating channels for a fixed radio link operating in an non-coordinated frequency band, wherein
   a predetermined and fixed number of channels are assigned to a plurality of radio links operating within a predetermined radio environment area,

   comprising the steps of
   allocating a respective distinct one or several of said predetermined number of channels to the corresponding number of radio links which are commissioned first, and
   for each additional radio link to be commissioned in excess of the number of predetermined channels,
   measuring the interference of each available channel allocated to the already commissioned radio links, and
   choosing the channel to be allocated to the respective additional radio link to be commissioned based on the interference measurement.

2. A method according to claim 1,

wherein
the channel with the lowest interference power among the available channels is chosen.

3. A method according to claim 1,
wherein
an arbitrary channel having an interference power below a predetermined interference threshold (TH_I) is chosen among the available channels.

4. A method according to claim 1,
wherein
an arbitrary channel with a signal interference ratio (S/I) above a predetermined collision threshold (TH_C) is chosen among the available channels.

5. A method for allocating channels for a fixed radio link operating in an non-coordinated frequency band, wherein
a predetermined and fixed number of channels are assigned to a plurality of radio links operating within a predetermined radio environment area,
comprising the steps of
allocating a respective distinct one or several of said predetermined number of channels to the corresponding number of radio links which are commissioned first, and
for each additional radio link to be commissioned in excess of the number of predetermined channels,
measuring the distance from each of the already commissioned radio links having an available channel allocated thereto, and
choosing the channel or channels to be allocated to the respective additional radio link to be commissioned based on the distance measurement.

6. A method according to claim 5, wherein choosing the channel or channels for the additionally to be commissioned radio link is effected by choosing the channel or channels which are used by the most distant ones of the radio links already commissioned earlier.

7. A method according to claim 5, wherein choosing the channel or channels for the additionally to be commissioned radio link is effected by choosing any of the channels used only by radio links at a distance larger than a predetermined distance threshold (TH_D).

8. A method according to any of claims 1 to 7, wherein the chosen channel or channels are manually allocated.

9. A method according to any of claims 1 to 7, wherein the chosen channel or channels are automatically allocated.

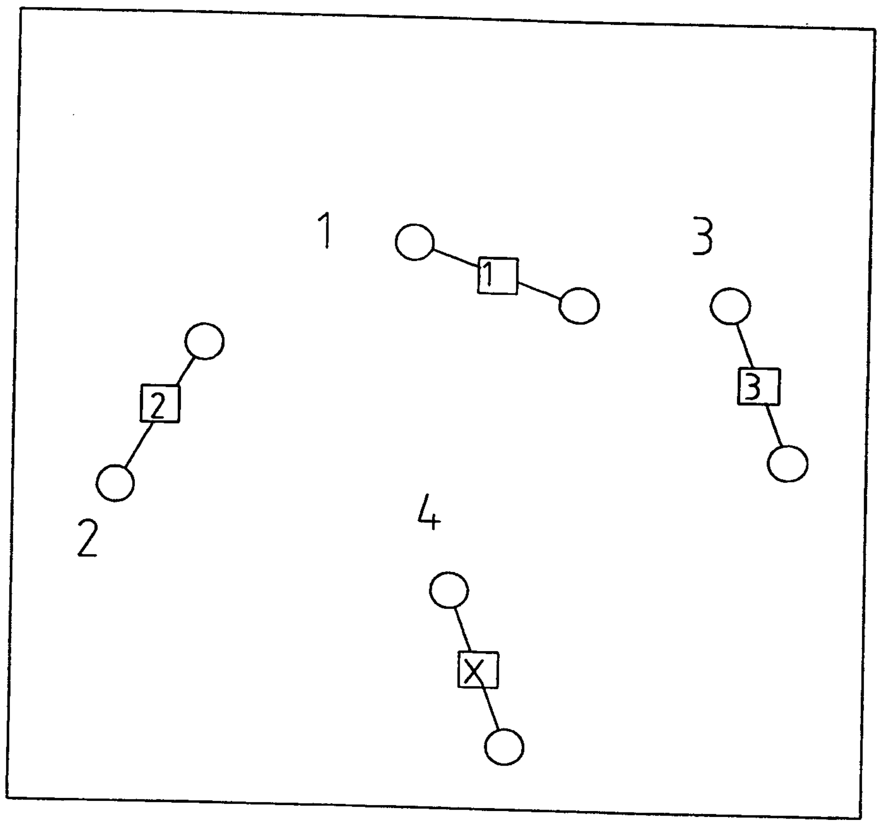

Fig. 1

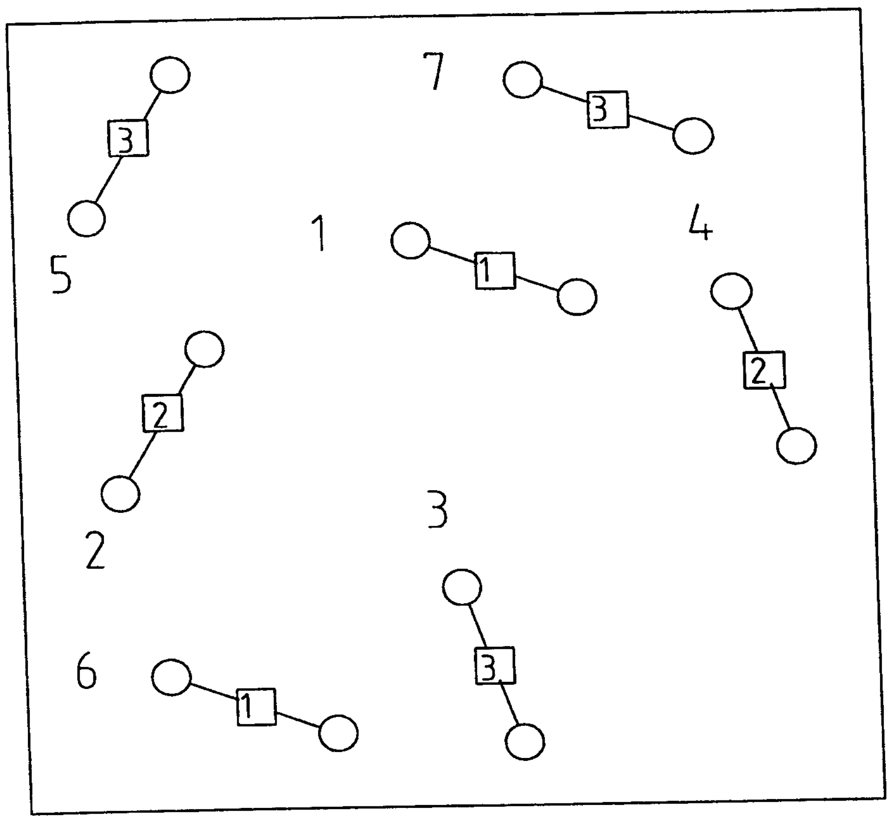

Fig. 2

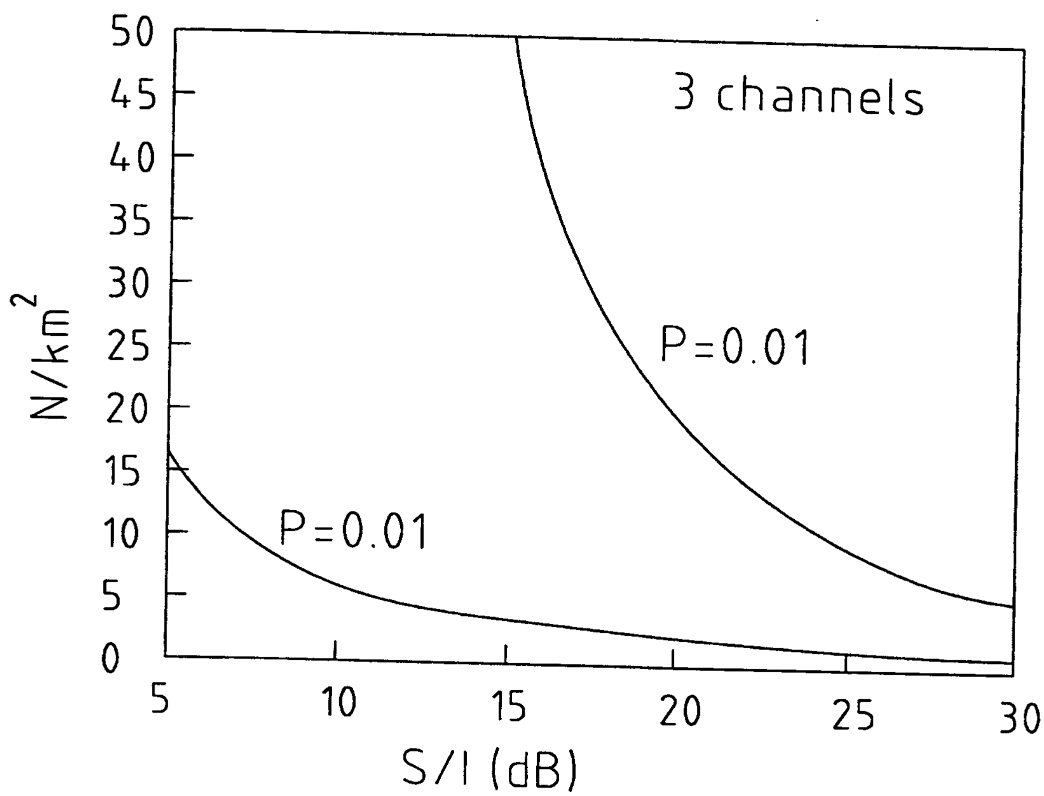
50
45
40
35
30
25
20
15
10
5
0
N/km^2
3 channels
P=0.01
P=0.01
5
10
15
20
25
30
S/I (dB)

Fig. 3

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 97/03314

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04B7/24

According to International Patent Classification (IPC) or to both national classification and IPC

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Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04B H04Q H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
29 April 1998	18/05/1998

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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